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Taxonomy of Automated Software Testing Tools

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Abstract- Several researches have been done already on software testing tools but there are no specific standards. It is very important to classify these tools in order to make correct choice among them. Without classifying them the functionality of these tools can't be understood. So in this paper, we are proposing and doing survey of the taxonomy of different testing tools and further more doing the comparison of these tools. Since there exists manual testing tools also but we are focusing on the just automated testing tools that are web based as well as application based. The comparison of various tools that are management, loading and functional have been done on the basis of their attributes such as Operating system support, Programming language support, Browser support, License and etc.

Keywords**:** *Software testing tools; Taxonomy; Survey.*

I. INTRODUCTION

The quality of a software product can be checked or evaluated based on the testing procedures that the product or software undergone. Basically testing [1] is an ongoing activity that is related with any process to produce a quality or working product. According to IEEE, Testing is the process of evaluating a system of system component by manual or automated means to verify that it satisfies required requirements [1]. So it is used to check the status of the working product after and during the software build. Software testing is also used to detect and identify the defects that the software may have. It is one of the vital parts of software development life cycle (SDLC).

Software testing can be done either by using automated or manual testing. By testing software through automated means is the best way to test the software. This testing of software is useful when repeated test scripts [1] are required or where the test scripts subroutine are generated. The one of the most important advantage of automation testing is its execution speed. On the other hand, manual testing requires testing manually which needs more time, more chances of error and is no more useful. Hence all issues of manual testing can be fixed using automation testing.

This paper demonstrates the taxonomy of different automated testing tools comprising of Functional, Management and Loading testing.

II. PURPOSE/OBJECTIVE

The purpose of our research is to conduct a survey and comparative study of the different testing tools available in market to ensure the quality of software products which will help the professional in order to fulfill the business needs and requirements.

Keeping in this mind, there exist many differences and similarities between these testing tools that have been compared based on their different attributes like Operating system, Language, license supports etc. Since many researches already have been done but we are interested to present taxonomy of different testing tools and performing their comparison. The main objective of software testing is discussed below.

- What are the challenges, an organization may face to use these testing tools to test the software.
- To describe the taxonomy of these tool.
- To find out defects that the software may encounter.
- To prevent these defects.
- To ensure that it meets the quality requirements.
- To ensure that it work properly.

III. LIMITATIONS

The scope of this research is to represent the taxonomy of different testing tools and then performing a comparative study of these tools. But this research is limited to some extent. During this research interviews will not conducted. To verify the performance of tools, test will not be conducted. Our field is restricted to software testing only. Full details of the testing tool is not described, but is some extent that someone understand the basic functionality of tool easily. Results are generated from the data received from different companies. Furthermore experiments results are not doing in this research.

IV. THEORETICAL BACKGROUND

This section will describe the basic and most commonly used terminology that are essential for any software testing that how will they work, their functionality, their role and their importance in software testing such that reader could easily understand them. The terms that are needed to discuss here before making the taxonomy and performing the comparison of these testing tools includes Black box testing, White box testing, Gray box testing, Automated and Manual testing, Commercial, Open source and Commercial trial.

Black box testing is the testing that has no concern with the internal details or structure of a software product. The testing strategies not found all the errors occurred in software efficiently so this testing is used to resolve this problem. This testing is concern with the functionality of the software product that it's working properly or not. White box testing is the testing strategy used to test the software and is concern with the internal structure or details of the software product. This testing is also called "Glass Box Testing" [1]. This testing ensures that the expected results meet with the actual results. Here the person who performing the test takes the test input from the program logic. By this testing, one can find out the hidden errors that are encounter by the software. Gray box testing is the testing strategy that consists of the combination of both white and black box testing. Here white box testing refers to the internal structure and black box refers not with the internal structure of the application. It is sometime useful when little bit internal information is available but not in detail.

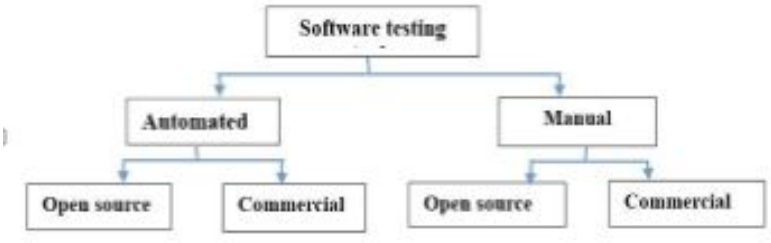

Figure 1: *Taxonomy of Software Testing*

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Software testing can be divided into automated and manual testing. These testing are used to find out the defects of the software. Automated testing means to test the software product using the automation. This testing is consider to be the vital part of testing software because of its benefits like execution speed of test cases, efficiency, reliability etc. More over this testing is time saving and not expensive because of the repeated test cases during development of software. In manual testing, human interaction is required to test the software. This testing is time

consuming and much effort and expenses are required to test the test cases again and again during development cycle of software. There are open and commercial testing tool available that we are discussed in our research. Open source tools are those that are freely available and are easily downloadable and install on the PC to do the test of web and desktop applications for example selenium. While Commercial source tools are those that are not available freely and require payments in order to use them for example Quick Test Professional. There are some other tools available that are commercial trial which mean that they are available freely to use during the trial and after completion of these tool trial, money is required to use it.

V. EVOLUTION OF AUTOMATION TESTING TOOL

Mohd Ehmer Khan described the different strategies for software testing tools that can be used to efficiently test the software like correctness, performance, Reliability and security testing which are classified by purpose and are classified into [4]. Manjit Kaur performed the comparison on automated tools such as QTP and TC. QT Pro and Automated QA Test Complete has been compared based on features including generating scripts, playing-back them, speed and cost [8]. Test Complete is easy to use and has a good impact for those applications that requires less security and similarly QTP has good impact for those applications where security is of more concern.

Sanjeev Dhawan performed automated testing of web based applications through *QTP* and *FSM Professional*. Model based testing refers generating test cases automatically. It is based on test generations, test strategies and techniques. Hewlett Packard QT Pro performs functional and regression testing. Another model based FSM technique with nodes describing System under Test (SUT) state and arc describing SUT actions. It allows the generation of adequate test cases.

Sanjay Tyagi performed a comparison study on the performance of various testing tools such as NeoLoad [9], WAPT [10] and Loadster [11] and their performance results are evaluated in different browsers. Basically performance testing [12] is a non- functional type of testing to ensure *speed, reliability, stability, and scalability* of system. The same website has been used to check the performance under these performance tools and their results has been compared to select the best tool among them.

Harpreet Kaur described the comparative study of automated testing tools like Selenium, QTP and TC and their performed is determine based on Efficiency, Licensing Costs, Application Support, Usage, etc. TC and Selenium has been compared with QTP [7][13] and their shortcoming are discussed in [6]. Among all QTP is the best tool among all.

VI. TAXONOMY

Taxonomy of different testing tools described in Figure 2. It has functional, management and loading testing tools. Some of the testing tools are open source available freely to use and some are commercially available that are not freely to use and money is required to use them. The basic description of functional, loading and management testing is below:

A. Functional Testing

It verifies that the application under test works expected or not. This testing can be used to record and modify the scripts. It consists of *quality assurance (QA)* process [51] and is black box testing. It is different from system testing. This testing verifies a program while system testing validates a program.

B. Management Testing

This testing is used to save the information about how the testing is done. This testing is also used in performing different activities like plan and quality assurance activities. Test management [41] tool offer the capability for data analysis and provide a communication among different project team members.

C. Loading Testing

Load testing is also called “Volume Testing” [1]. This testing is used to ensure that how much load on an application or a system can bear with predefined circumstances. It based on that the response of system is checked. This testing

simply refers to the maximum load a system can have. By using this testing, basically behavior of a system is determined. If a load on a system increases its certain level then it is called *stress testing.*

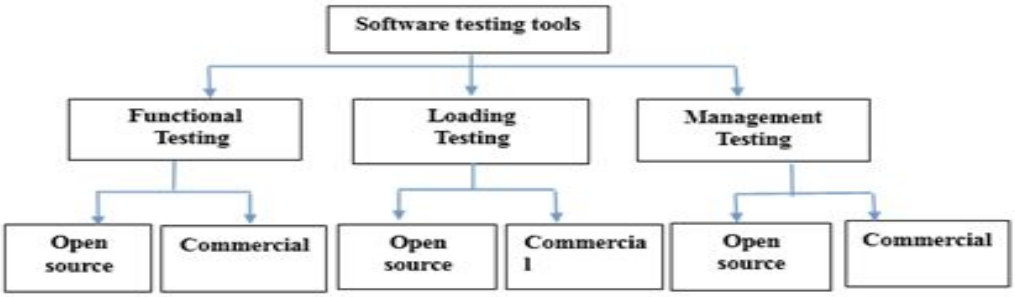

Figure 2: *Taxonomy of Software Testing Tools*

VII. CRITERIA FOR TOOLS COMPARISON

Individual tools can be compared according to various criteria; since they are used for same purpose they will also have similar characteristics. Basic criteria designated for comparison of the available tools are described in the below Table.

Table 1: *Criterion Description*

Supported Web Browsers	Does the tool support testing of web- based applications for the most common Web browsers? Important are both desktop and mobile web browsers.
Licensing	Licensing requirements for commercial use.
Website	Official address or place where all information are provide about specific things.
Price	Price of the tools for commercial use.
Supported platforms	Support for most widely used operating systems and their different versions.
Supported programming languages	Support for different programming and scripting languages

VIII. SELECTED TOOL FOR COMPARISONS

We have selected 32 best tools for our research that are automated tools. Their description is stated below.

- ***Selenium:***

Selenium [14] consists of four tools Selenium IDE, Selenium RC, Selenium Web Drive and Selenium Grid. Selenium is a tool that is easy to use and freely available. It is automated tool used to test web application. This tool supports different browsers. All components of the project are released under open source license Apache 2.0 [15]. Jason Huggins developed this tool in 2004. Now a day's selenium has made a huge improvement as a strong web based automated tool [16] [17].

- ***Ranorex:***

It is also an automated tool that tests the web applications and is not freely available. It is best tool for Easy installation for non-programmers. This tool can be used for object identification like automatic UI object synchronization, use of Xpath expression, robust object identification etc. while selenium does not offer these features. Moreover it provides the features for reusability [18].

- ***Test Complete:***

Test Complete [8] is an automated testing tool that is used to perform management, creation related tasks. It is used to run tests for any Windows, Web. Its purpose is to create highly qualified software tests [19].

- ***HP –QTP:***

QTP [7] is the part of HP quality center toolsuite2. It uses functional and regression testing for most of the applications. In 2006, it was first written by Mercury Interactive4, and then acquired by Hewlett Packard [21].

- ***Watir:***

Watir [22] is pronounced as water. It is used to test web applications and this is freely available and mostly used these days. This tool uses scripting language called *ruby*. It is light in weight and supported by multiple browsers.

- ***TOSCA****:*

Tosca [23] supports regression and functional testing for testing software test management. This tool is mostly useful in smaller, larger and multi projects. The main advantage of using this tool that it maintains the history changed of any working product.

- ***FitNesse****:*

Fitnesse [24] is a tool that is used to test the tables. It is a wiki wrapper which provides a web interface to the test suite. It allows tester and developer to create tests cases on wiki. It provides communication and collaboration in developing software. It can be used to test applications that are written in JAVA, PHP, PYTHON etc.

- ***LoadRunner:***

LoadRunner [25] is a load testing tool so it is used to determine the performance and behavior of web application, mobile applications that provide a correct end to end performance view. It can be used to identify errors and correct them before deployment of any product. This tool reduces the programming skills required to test the product. It tests the applications faster and easier.

- ***SilkTest****:*

SilkTest [26] is an automation robust tool for testing web and enterprise applications. It is functional testing tool as well as regression testing tool which is cost effective and test the above mentioned applications efficiently and in a well manner. This tool save the time, test the scripts effectively and test multiple platforms and browsers. It was developed by Segue Software Inc. which was acquired by Borland in 2006 and later Borland was acquired by Micro Focus International in 2009.

- ***TestNg:***

TestNG [27] is the next generation testing tool which is impressed from NUnit7 and JUnit6. It is easy to use and most perfect tool for testing.

- ***WinRunner:***

HP WinRunner[28] software is an automation testing tool which focuses on the graphical user interface testing. Main advantage of this tool is to recover all those operations that were deactivated due to exception or some other reason. It was initially made by Mercury Interactive.

- ***Apache Jmeter:***

Apache Jmeter [29] is developed by Apache Software Foundation (ASF) and is open source tool. This tool again used as a load testing tool for determining the performance of various web applications. It also support for functional testing. It's features consists of HTTP, Web services and JDBC database connections etc.

- ***SoapUI:***

SoapUI [30] is a freely available and open source testing tool for functional testing and web testing. It has a very interactive graphical user interface and some other features so that it can be used to perform regression, load and functional tests efficiently. It is developed by Smart Bear Software. The set of features offered by SoapUI helps in performance evaluation of web services. Quality of application and services can be improved by performing analysis of test results.

- ***Storm****:*

Storm [31] is an open source and free tool for testing the services provided by web. It is coded in F# language and is freely available under BSD license. It mostly test the services provided by the web that are mostly coded in .NET and java. It is very easy to use because it provides an interactive graphical interface. It can be used to test multiple web services at the same time which in turn save the time consumption and improve the efficiency.

- ***Visual Studio Web Tests**:*

[32] A product of Microsoft available since Visual Studio 2005. Web Test has been chosen for this paper because it is famous among dot NET developers since that it is shipped freely with the Visual Studio. A test scenario is written by the tester and recorded by him as well; the series of HTTP requests are recorded. When play back is performed, these requests are generated in the same order as were recorded by the web test. According to [33], working of the application as well as the stress testing is performed by the *web tests.*

- ***Sahi:***

Sahi [34] another open source and free automation tool specially designed to support cross- browser testing for web applications with lots of AJAX and dynamic content [35]. Sahi injects JavaScript into web pages with the help of a proxy in order to automate web pages. Sahi seems to have a more reliable record/playback tool compared to Test Complete. Also, during the comparison, Sahi appeared to have much more effectiveness when processing web page waits (waiting for the web page to load completely). Test scripts are exported in JavaScript to enable good programming control [35]. Test scripts were very robust during comparisons; there was no need to script statements for page waits. Sahi supports data-driven tests, and can be easily connected to Excel, database or CSV files.

- ***GEB**:*

Geb [36] is an automated tool for web browsers solution that creates a connection between web content and web browser. It uses the Groovy language to provide a strong content definition DSL and jQuery which is a strong content inspection. It is easy to use and can be productive and is a developer tool.

- ***NeoLoad**:*

[37] It is a tool for web applications that can be used to check the performance of entire website by putting a heavy load on it. It is to be analyzed that how it performs under such severe conditions.

- ***WAPT**:*

[38] It is a tool used in determining the performance of web application. It is also used to check the output of web application or their interfaces. It is easy to use and determines the performance of a web application by putting load beyond the certain level which would be stress testing and within the load limits would be a load testing.

- ***WebLOAD**:*

WebLOAD [39] this tool also use to determine the performance to a web based applications in term of stress and load testing. Generally speaking, this tool provide the functionality and capacity of the web applications how much they can bear.

- ***Testing Anywhere**:*

Testing anywhere [40] is testing tool which automatically analyze the performance of web apps, web sites and other objects. Since this tool automatically tests any application that is under test so this tool can be used to find out any defects and then correct them.

- ***Rational Performance Tester**:*

[41] [42] is an automated testing tool that is used to determine the performance of web or server based apps. This testing tool is mostly used when there requires input and output.

- ***LoadUI**:*

LoadUI [43] is freely available and load testing tool which can be used to check the performance of the web based application. When this tool is used with the SoapUI then it really works efficiently. LoadUI is the most flexible and interactive testing tools. Its report and advance specifications allow to determine the actual performance by using the new data as the application has been tested.

- ***Wizdl:***

Wizdl [44] is a .NET framework and it is made in C#. This tool is used to test web performing services using an effective way of window forms i.e. with a graphical user interface. Complicated services provide by web which take nested objects and arrays as a parameter can easily called. The tool provides the facility of storing data in XML file format which can be later used for regression testing.

- ***SOA:***

Cleaner: SOA Cleaner [45] is an open source web service tool developed by Xyrow. It is written in dot Net and provides GUI platform to enter web service description language to test web service. SOACleaner also supports REST testing. The main benefits of SOA Cleaner it is simple to use without the need of coding knowledge. SOA Cleaner supports .NET and Java framework. SOA Cleaner offers more efficiency and usability.

- ***Wcf Storm:***

Wcf Storm [31] is an open-source and freely available tool for testing web. Its source code was written in F# language. It tests the services of web using like dot Net, Java, etc. Storm supports dynamic invocation for those methods that has input parameters of complicated data types. Raw soap requests can be efficiently edited and manipulated by it. Its graphical user interface is simple and easy to use.

- ***Xebium****:*

Xebium [46] is a tool for creating automated integration, acceptance and regression tests. It can be used as a testing framework for functional testing of the user interface of web applications. Xebium is a combination of three frameworks. These are Selenium IDE, Selenium Web Driver and Fit Nesse.

- ***Tellurium****:*

[47] It is a tool for automated testing of web applications based on the Selenium RC framework. The tool has been developing since 2008 and it is regularly updated. It is freely available with apache 2.0 license like Selenium.

- ***WebTest****:*

WebTest [48] is a simple framework for automated testing of web applications, written in Java. Test scenarios are executed under a virtual interpreter HtmlUnit included in the distribution. The main advantage of the Html Unit is in speed of the test execution, because tests are not executed in the real graphical user interface of the browser. This virtual browser simulates manner in which is JavaScript processed in the Internet Explorer and Firefox web browser.

- ***Janova:***

[49]: This is an automated testing tool by which testing is done on the cloud. This tool uses English like tool that fulfill software implementation task with an efficiency and effective way. There is no software to download and no infrastructural investment required [44]. It is quick, easy setup with no installation required and is used to navigate home page easily.

- ***Telerik Test Studio:***

[50] It is the comprehensive commercial system based on the WebAii framework, and therefore provides support for the same web browsers and frameworks for unit testing. However, it also comes with many features that are available to users through a transparent GUI. It also provides support for recording test scripts as a plugin for the Internet Explorer.

- ***Appvance****:*

Appvance [20] Performance Cloud (APC) is a nice platform for testing those applications that are developing in this era. This testing tool uses functional and performance techniques to test these applications such as web, AJAX app etc. Modern applications are very difficult to test but Appvance gain its popularity just because of the fact that it solves that problem. It tests these applications with improved speed and it's easy to use. Some advantages that it has over others are 1) full agile support 2) Faster testing 3) Improved productivity 4) Full beginning to end testing 5) UXAVATAR technology.

IX. COMPARISON OF TOOLS

In this section, comparison of selected tools are performed based on their attributes such as operating system, browser support ,license , cost and some other attributes shown in a below table.

Table 1: *Comparison of Tools on various criteria*

Sr. #	Name of tool	Operating system	Browser supports	License	Application Support	Language Supported	Cost
1	Selenium	Cross platform	All major browser	Apache 2.0	Software testing framework for web application	Java, C#, PHP, Ruby, Python, Perl	Open source
2	Watir	Cross platform	Internet Explorer, later supports many browsers	BSD	Software testing framework for web application	Java, .NET, C#	Open source
3	Test Complete	Microsoft windows	IE, Firefox, Google chrome	Proprietary	Test Automation Tool	VBscript, JavaScript, C++, Delphi Scriptc #Script.	Commercial
4	FitNesse	Cross platform	Platform independent	CPL	Test Automation Tool	C++, Python, C# Ruby, Delphi, etc.	Open source
5	HP-QTP	Microsoft windows	IE 6,7,8,10, Firefox 3.0 and later, chrome	Proprietary	Test Automation Tool	VBscript	Commercial
6	Win Runner	Windows, Linux	Internet Explorer, Netscape	Proprietary	Load Testing Tool	Test Scripting Language (TSL)	Commercial
7	TOSCA	Microsoft windows	IE, Firefox	Proprietary commercial	Test Automation Tool	Delphi, .NET , java	Commercial
8	Silktest	Windows	Internet Explorer, Firefox	Proprietary	Test Automation Tool	Java, 4Test, VB, c#, VB.net	Commercial
9	HP Load Runner	Windows, Linux	Any browser	Proprietary	Load Testing Tool	VB, VBscript, java, C#, JavaScript	Commercial
10	TestNG	Window, Linux, MAC	IE, Firefox, Google chrome	Apache 2.0	Testing Framework	Java, also include more object oriented feature	Open source
9	HP Load Runner	Windows, Linux	Any browser	Proprietary	Load Testing Tool	VB, VBscript, java, C#, JavaScript	Commercial
10	TestNG	Window, Linux, MAC	IE, Firefox, Google chrome	Apache 2.0	Testing Framework	Java, also include more object oriented feature	Open source
11	JMeter	Cross platform	Chrome	Apache License 2.0	Web Application	Java	Open source
12	Storm	Microsoft Windows	-	New BSD License	Web Application	F#	Open source

13	soapUI	Cross platform	-	GNU LGPL 2.1	Web Application	Java	Open Source
14	GEB	Microsoft Windows, Linux and DOS	IE, Safari, Firefox, Chrome, Opera	Open source based on groovy	Web and desktop Application	Groovy	Open source
15	Ranorex	Microsoft windows	Opera, Firefox, Netscape, IE, Chrome	Proprietary	Web and desktop Application	C#, VB.Net, Python	Open source
16	Janova	Cloud	IE (8+), Firefox Chrome, Safari,	janova	web application	Ruby	Commercial
17	Tellurium	Windows , Mac OS X, Unix	All major browsers, Android, IOS, Blackberry proprietary browsers.	Apache 2.0	Web applications	Java, Groovy	Open source
18	WebTest	windows, Mac OS X, Unix	Html Unit	Apache 2.0	Web applications	Java, Groovy	Open source
19	Wizdl	MS Windows	-	GPLv2	Web services	C#, .NET, Java	Open Source
20	Wcftstorm	MS Windows8/ 7/ vista/XP/ 2000/NT	-	BSD	Web services	F#, .NET	Commercial
21	SOA Cleanr	MS Windows	-	Freeware	Web services Java,.net	C#, .NET 2.0	Freeware
22	Xebium	windows, Mac OSX, Unix	All Major, Android, iOS, Blackberry proprietary browsers.	Apache License version 2.0	Web applications.	Java, C++, Ruby, Python, Delphi, C#	Open source
23	wapt	Windows OS, unix	IE, Chrome and Firefox browser	Proprietar y	Web, mobile load testing application	Asp.net	Open source
24	WebLO AD	Windows, Linux, Unix	IE, Chrome and Firefox browser	proprietar y	Web, mobile load testing application	Java, .Net. php, JavaScript	Open source
25	NeoLoad	windows, Linux and Solaris	(latest Chrome and Firefox browsers	proprietar y	Web, mobile load testing application	Javascript, .NET, php	Open source
22	Xebium	windows, Mac OSX, Unix	All Major, Android, iOS, Blackberry proprietary browsers.	Apache License version 2.0	Web applications.	Java, C++, Ruby, Python, Delphi, C#	Open source
23	wapt	Windows OS, unix	IE, Chrome and Firefox browser	Proprietar y	Web, mobile load testing application	Asp.net	Open source
24	WebLO AD	Windows, Linux, Unix	IE, Chrome and Firefox browser	proprietar y	Web, mobile load testing application	Java, .Net. php, JavaScript	Open source

25	NeoLoad	windows, Linux and Solaris	(latest Chrome and Firefox browsers	proprietary	Web, mobile load testing application	Javascript, .NET, php	Open source
26	LoadUI	Cross platform	Chrome and Firefox browsers	EUPL	Web, mobile application	Java, Javafx, groovy	Open source
27	Appvance	ALL platform	All Major, Mobile Web browsers	free automation	Web, Ajax , Message, mobile apps, SOA services, Oracle	php, Perl Python, Groovy ,Ruby, C#, Java	Open source
28	Test Anywhere	Windows OS	IE, Chrome and Firefox	Shareware	web application	Java, Silverlight , .Net, mainframe, C++	Open source
29	Rational Performance Tester	AIX, Linux, Windows	IE, Chrome and Firefox browsers	proprietary	web application	java	Commercial
30	Sahi	Cross browsers	IE, Firefox	Apache 2.0	web application	Java, php, JavaScript, Python, and	Open source
31	Visual studio	Windows OS	IE, Mozilla Firefox and Google Chrome,	proprietary	web application	C++, C#, .Net	Commercial Trial
32	Telerik Test Studio	Windows, iOS	All Major and iOS	Commercial single license	Web applications	C#, .Net	Commercial

X. PROS

- Fast execution of test cases.
- Test software in a less amount of time.
- All issues of manual testing are resolved by automatic testing.
- Repeated test cases are handled easily.

XI. CONS:

- Knowledge and skills are required to use these tools.
- Some automation tools are not freely available and are expensive. .
- Maintenance is a difficult task and might be expensive.

XII. CONCLUSION

In this paper, the taxonomy of different testing tool has been presented such as functional, loading, and management test automation. Now testing through automation tool has become the necessity of today era. Because it not only save time but also save the manual effort required to test the software for error. The selection of tool requires the requirement gathering and to categorize them in a well manner. This will help a lot to evaluate the tool in a best manner. As many automated software testing tools are available in market and are used to test software but we conducted a comparative study of 32 best tools and suggests some tools that are mostly used in market for automation testing based on the strategy discuss above. These tools include Selenium, Ranorex, Soap UI, FitNessee, Appvance, Apache J meter, HP- QTP, Test Complete and Telerik Test Studio.

FUTURE WORK

According to our point of view the best tool is one that is freely available, easy to use and support all the languages. For the best results, comparison of these tools can be made using the experiments in future.

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